A system for synthetic vision and augmented reality in future flight decks

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ABSTRACT

Rockwell Science Center is investigating novel human-computer interaction techniques for enhancing the situational awareness in future flight decks. One aspect is to provide intuitive displays that provide the vital information and the spatial awareness by augmenting the real world with an overlay of relevant information registered to the real world. Such Augmented Reality (AR) techniques can be employed during bad weather scenarios to permit flying in Visual Flight Rules (VFR) in conditions which would normally require Instrumental Flight Rules (IFR). These systems could easily be implemented on heads-up displays (HUD). The advantage of AR systems vs. purely synthetic vision (SV) systems is that the pilot can relate the information overlay to real objects in the world, whereas SV systems provide a constant virtual view, where inconsistencies can hardly be detected. The development of components for such a system led to a demonstrator implemented on a PC. A camera grabs video images which are overlaid with registered information. Orientation of the camera is obtained from an inclinometer and a magnetometer; position is acquired from GPS. In a possible implementation in an airplane, the on-board attitude information can be used for obtaining correct registration. If visibility is sufficient, computer vision modules can be used to fine-tune the registration by matching visual cues with database features. This technology would be especially useful for landing approaches. The current demonstrator provides a frame-rate of 15 fps, using a live video feed as background with an overlay of avionics symbology in the foreground. In addition, terrain rendering from a 1 arc sec. digital elevation model database can be overlaid to provide synthetic vision in case of limited visibility. For true outdoor testing (on ground level), the system has been implemented on a wearable computer.

Keywords: Augmented reality, synthetic vision, future flight deck, cockpit displays, wearable computing

1. INTRODUCTION – MOTIVATION FOR NEW FLIGHT DECK DISPLAYS

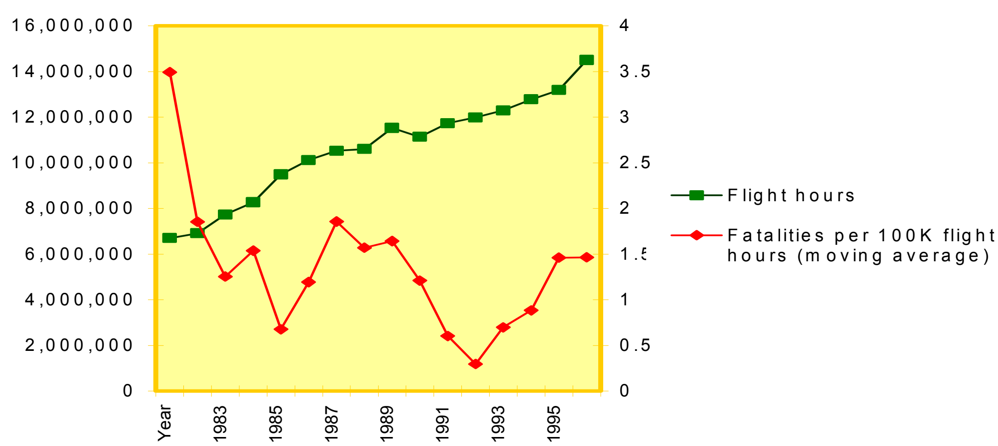

Fig. 1. Statistics of fatalities per flight hours (source: NTSB).

The number of aviation accidents per million of traveled miles has continuously decreased since the 1950s, but has "leveled out" to a constant plateau since the late '70s. This trend is also evident in the number of fatalities, as shown in

Fig. 1. Due to expected dramatic increases in the volume and density of air traffic, this "flat" accident rate may result in large numbers of accidents and fatalities over the next few decades. Therefore, the US government has issued a mandate to reduce accident rates by a factor of five in the next ten years, and by a factor of ten within 20 years. Statistical data from NTSB reveal that human factors are the cause of up to 75% of all accidents in civil aviation. Over 30% of all general aviation accidents are influenced, at least in part, by weather. Controlled flight into terrain (CFIT) is the leading cause of fatal accidents in commercial aviation (29% of fatal large jet accidents worldwide between 1991 and 1995), and runway incursions contribute to 7% of all fatal accidents[2]. Weather, terrain, and other aircraft are also relevant factors in aircraft incidents[9].

Improving the situational awareness of pilots would help reduce these numbers of accidents significantly. In light of the future free-flight paradigm (FAA, 1981)[5, 6], pilots will have an increased responsibility for their flight plan, which means that they will have to receive and process more information than currently. This requires new modes of information displays, which are capable of providing the vital and necessary information intuitively, without causing an information overload to the pilot. Automated landing systems are being developed[8], and the use of computer-generated imagery was suggested by NASA[1] for future flight decks. Such displays should provide weather information, other traffic[14], terrain rendering, own flight path, and other relevant information. Completely synthetic rendering could provide a "tunnel-in-the-sky"[11], indicating the flight path and ensuring that neither an obstacle, nor other traffic, leads to a collision[10]. Synthetic vision (SV) is an intuitive and promising way of presenting information to the pilot to increase his situational and spatial awareness, because it exploits the natural 3D vision capabilities and modalities, which the pilot uses in daily life. Certain heads-down hazard displays (weather, traffic, or terrain) are already commercially available[7], and these displays use digital terrain maps and GPS geo-location data to visualize the flight path and certain hazards to increase situational awareness. These systems, however, neither provide sufficient graphical detail (low resolution), nor integrate all available sensory information (e.g., weather satellite data). More sophisticated displays have been tested, but another problem arises: the high quality of the visualization does not convey awareness for possible errors in the database or the sensor measurements and, therefore, often reduces the actual spatial awareness of pilots who rely too much on the realistic visualization[12, 13].

A step towards a more realistic display is the integration of a live view from the outside with SV visualization elements. This can be achieved by overlaying synthetic vision renditions onto images, captured by cameras with a viewing area outside of the aircraft, or by rendering synthetic vision elements onto heads-up displays into the view of the pilot. This approach provides an augmentation of the visual view (augmented reality) and enables the pilot to quickly verify the synthetic vision display information. Of course, this kind of Augmented Reality (AR) display cannot be used in visibility conditions which completely prohibit visual flight rules (VFR), because in that case, the visual image from outside would not be usable. In this case, the system would provide a fully rendered SV environment for the pilot to fly the plane according to the VFR rules.

The AR research done at Rockwell Science Center (RSC) has led to a variety of systems applying AR technology[4]. This human-computer interface method is very well suited to provide intuitive information to a user by placing relevant information – either textual, iconic, or fully rendered 3D objects – directly into his/her view. In this paper, we describe the application of AR techniques for a novel cockpit display. We are using the framework, set up for other projects in this domain[16].

2. VISUALIZATION

Two methods of display rendering have been implemented by RSC:

- A fully rendered 3D display of terrain, requiring a graphical workstation.
- A simple 2D overlay with grid lines and horizon silhouettes, just requiring low computing power.

Both types of displays have been developed for Thousand Oaks, CA, where RSC is located. This allows an easy verification of the system by simple "testing-on-the-ground". The terrain is well structured (hilly terrain) and, therefore, shows enough features to compare the real view with the synthetic view.

2.1. 3D Terrain Rendering “ARscape” – Synthetic Vision

The 3D terrain rendering system “ARscape”, developed by RSC for a general multi-modal display[16] in another project, is based on 1 arc sec. (approx. 30m) resolution National Elevation Data (NED) from the area around RSC. The terrain database was created using the TerraVista® software from TerreX®. Photo realistic aerial images and topographic contour maps from USGS were used for the terrain skin’s texture. Figure 2 shows the 3D terrain visualization of this dataset. The photographic images were only applied to a smaller region. Therefore, the region in the background is rendered lighter with just contour data. ARscape is a Microsoft® Visual C++ application using the VTree® API from CG2® for rendering. VTree is a platform independent (NT or UNIX) 3D graphics toolkit built on top of OpenGL®. It also supports the TerraPage® fast database paging format output by TerraVista®. The ARscape system is implemented on an SGI 320 NT workstation.

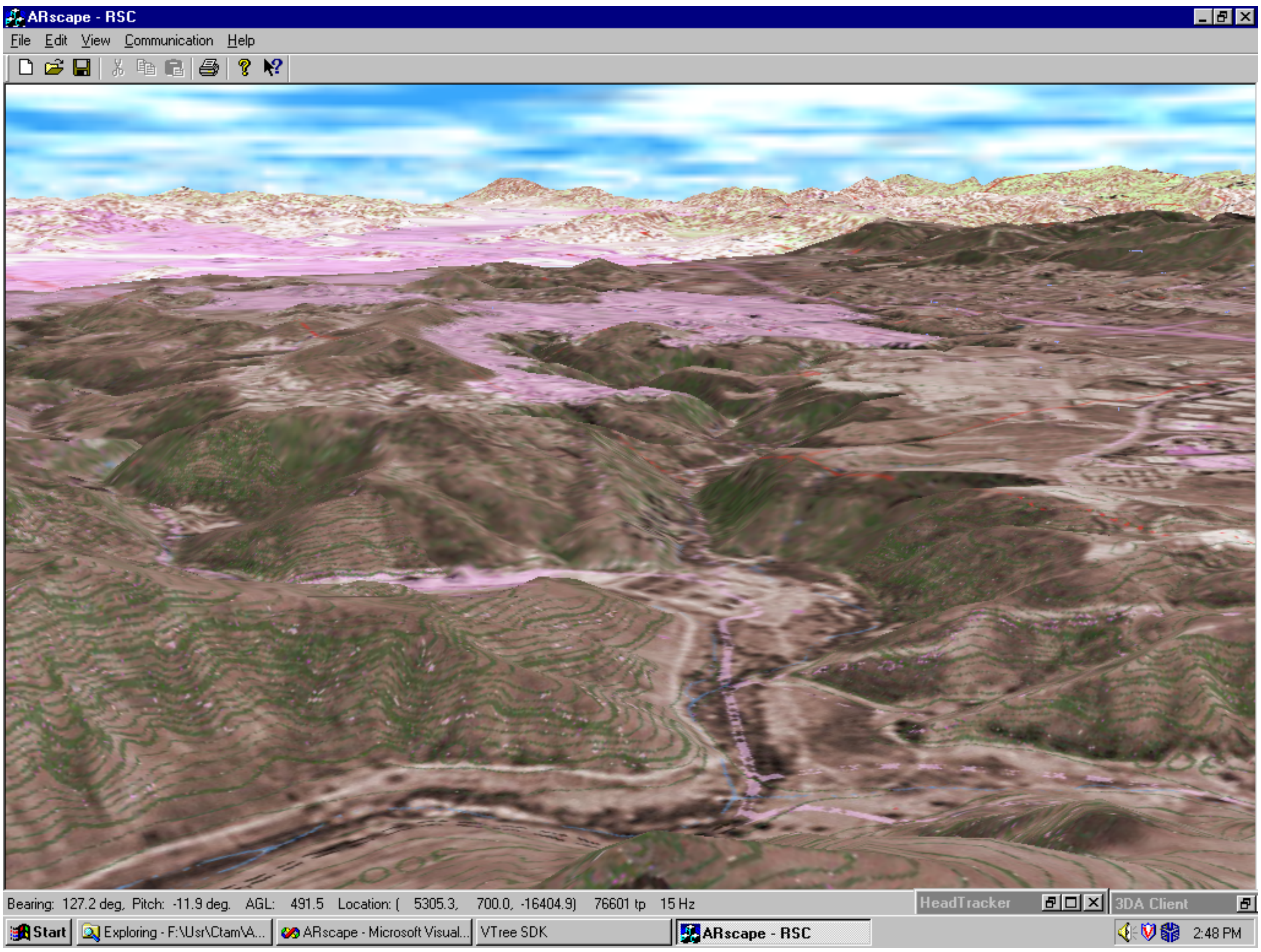

Fig. 2. Screenshot of the ARscape 3D terrain rendition, based on NED data, aerial photographs, and topographical map. The two minimized window (lower right corner) indicate connections to a head tracker and a 3D audio client. The lighter area in the background does not show the photographic texture map of the aerial image.

A panoramic image constructed from a large number of narrow angle shots was applied to a cylinder of matching aspect ratio, centered at the location of the shot. The radius of this cylinder is set large enough that the cylindrical wall completely surrounds the gaming area. Then the observer location is set to be the same as where the shot was taken. The resulting image, covering roughly 93 degrees in horizontal field of view, is attached. The profile match agrees well despite an obvious tilt of the image in the anti-clockwise direction, which is attributed to an unintended non-vertical alignment of the axis of the turntable for the camera taking the panoramic shot. View for the remaining 267 degrees is not shown, as the gaming area in this interim database is too small for valid comparison in those directions. In this mode, the ARscape display system is set to render the terrain as wireframe. This demonstrates the reduced rendering under clear visibility conditions, where the pilot can see the real world and does not need a completely synthetic vision terrain rendition (see Fig. 3).

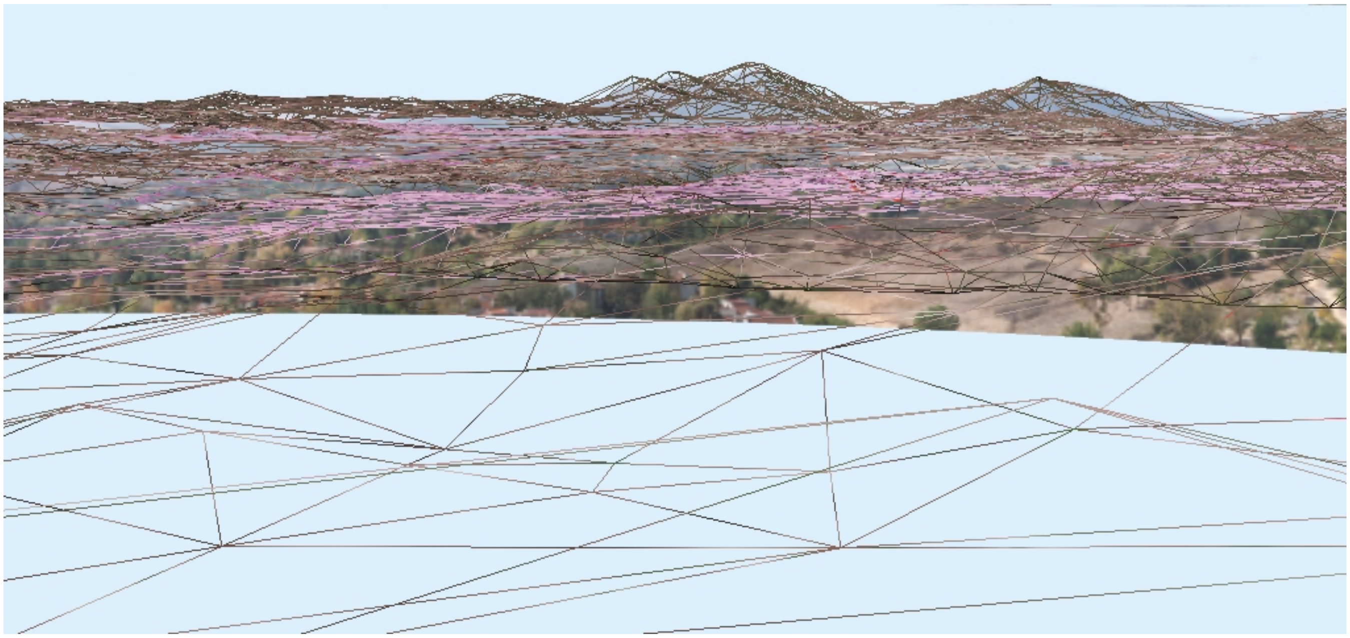

Fig. 3. Overlay of wireframe terrain rendering onto surround photographic image of the outside world. This image is a static image and only demonstrates the overlay capability. In a real application, this image will be replaced with a live captured video steam.

2.2. Simple 2D GDI Overlay on Video – Augmented Reality

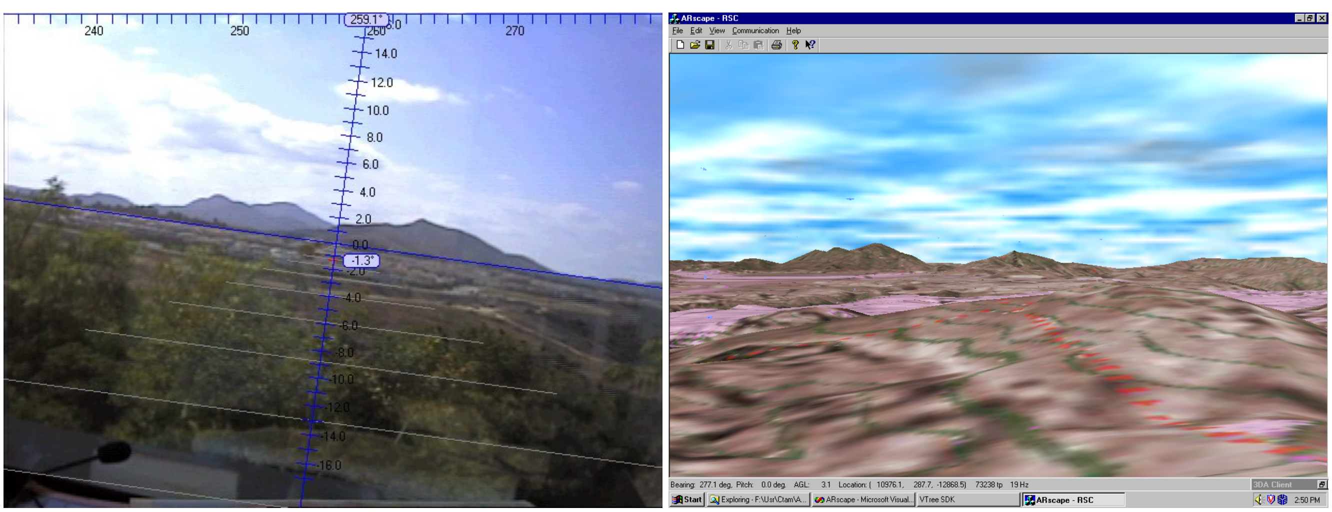

Fig. 4. Left: Real-time overlay of grid onto video stream, captured by a camera. Right: Terrain rendition by ARscape from a nearby vantage point in the same direction as the camera image.

When the real world is clearly visible, detail terrain visualization is not required and may even be distracting by obscuring real world elements. Therefore, a simple 2D overlay mode – using simple graphical display interface (GDI) methods – was developed for providing visual guidance clues for navigation and for avionics symbology. In Fig. 4, the two visualization modes are compared side by side for a similar viewpoint. The real world is captured by a camera and provides a live video background. If implemented on a HUD, the camera feed would not be necessary, as the pilot can see the terrain directly. This kind of visualization system is useful in structured terrain, during approaches (visualization of runway boundary), and for taxiing on the ground.

The AR overlay requires precise calibration, otherwise the overlay symbology will not match the real terrain features. An approach for registration has been presented using silhouette contours[3]. Also, other features could be used to align the internal information representation with the real world, utilizing an approach for real-time registration by visual servoing[15].

3. A WEARABLE DEMONSTRATOR FOR AUGMENTED REALITY HUD

Fig. 5. Wearable demonstrator for head-mounted immersive visualization for both 3D terrain visualization and simple GDI overlay for true Augmented Reality visualization.

In related work at Rockwell Science Center within the domain of "Augmented Reality", we have developed a wearable system which is capable of demonstrating AR principles. Since we currently do not have a true HUD display available, this wearable head-mounted display (HMD) serves as a substitute. The system is based on a Xybernaut® wearable computer MA IV (233 MHz Pentium processor), which can either provide the simple GDI overlay graphics for see-through AR, or serve as a communication interface to a larger graphics workstation.

In both cases, the wearable PC is polling a head tracker – mounted on a set of headphones – to obtain the viewing orientation of the user. This head tracker is a CyberTrack® CT-3.2, which provides yaw angle (by magnetometer measurements) and pitch/roll angle (inclinometer). The precision is ± 5 deg for yaw and ± 1 deg for pitch and roll angle, which is not sufficient for precise overlay. Future work will focus on improving registration by using visual registration methods[3]. However, this tetherless system allows the user to move around freely in an outdoor scenario.

The display is a bi-ocular, non-stereo SONY glasstron®, which can show 800x600 pixel resolution, if connected to a SVGA output by cable. In the completely wireless mode, however, the resolution is limited to NTSC video resolution. Batteries and CPU unit are mounted on a "jacket", distributed by Xybernaut®, which allows easy handling. If used in the full ARscape terrain rendering mode, the head orientation is sent through a wireless link (Proxim WaveLan®) to the SGI 320, which renders the terrain according to the viewpoint. The resulting image is then converted to NTSC and transmitted through a Coherent® video transmitter. The complete wearable system is built from commercial off-the-shelf (COTS) hardware.

4. CONCLUSION AND FUTURE PLANS

The framework developed for the RSC Augmented Reality projects[16], could be used efficiently for demonstrating technology development for future flight deck displays. Both the synthetic vision as well as the GDI display methods could be shown in stationary and mobile/wearable implementations. The only module currently still under development, is a GPS receiver module, which will provide true position data to the mobile user in order to provide correct location. With this system, the algorithms for registration can be tested before actual flight tests are conducted. Correct aviation symbology will be included in both displays.

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